Appendix F

Technical Memorandum:

Review of Design Criteria for Stormwater Quality Treatment Facilities for the Sacramento Stormwater Management Program

Sacramento Stormwater Management Program

Review of Design Criteria for Stormwater Quality Treatment Facilities for the Sacramento Stormwater Management Program

Prepared for the Sacramento MS4 Permittees:

City of Citrus Heights
City of Elk Grove
City of Folsom
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Technical Memorandum

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Introduction

1.1 Background and Purpose

This draft technical memorandum has been prepared for the County of Sacramento and the Cities of Sacramento, Citrus Heights, Elk Grove, Folsom, and Galt (Sacramento MS4 Permittees) who discharge stormwater from municipal separate storm sewer systems under Waste Discharge Requirements Order No. R5-2002-0206 (Sacramento MS4 Permit) issued by the Regional Water Quality Control Board (RWQCB). The purpose of this technical memorandum is to review the numeric design criteria in current use by the Sacramento MS4 Permittees for sizing structural stormwater quality treatment best management practices (BMPs), or stormwater quality control measures, and to determine whether the criteria are compliant with the Sacramento MS4 Permit.

Currently, stormwater facilities must be designed according to City and County of Sacramento standards. The Sacramento County Water Resources Division and the City of Sacramento Department of Utilities Division of Engineering have jointly developed the hydrology design standards for the City and County, which are documented in *Sacramento City/County Drainage Manual, Volume 2, Hydrology Standards* [Hydrology Standards] (Sacramento County Public Works Agency and City of Sacramento Department of Utilities and Public Work, 1996).

The Hydrology Standards provide a consistent basis for the analysis and engineering design of drainage facilities in the City and County of Sacramento. The Hydrology Standards also provide a method, called the Sato method, for estimating the storage volume required for the design of stormwater quality control detention basins. The Sato method, named after the engineering firm that developed it, was initially documented in a report published in 1991. The Sato Method was based on the precipitation records and technology available at the time. The Sato method is generally intended to size regional-sized water quality stormwater detention basins.

The City of Sacramento defines regional stormwater quality control measures as being for drainage areas of 100 acres or greater (City of Sacramento Department of Utilities and Public Work, 2000). These measures are typically built to receive and treat stormwater discharges from multiple upstream developments.

Measures for smaller drainage areas are called on-site measures and are typically constructed to treat stormwater discharges from a single upstream development. Currently, these stormwater quality control measures should be designed using the *Guidance Manual for On-Site Stormwater Quality Control Measures* [On-Site Guidance Manual] (Sacramento County Public Works Agency and City of Sacramento Department of Utilities and Public Work, 2000).

Recently, the Central Valley Regional Water Quality Control Board (RWQCB) issued an MS4 Permit that includes very specific requirements for volume- and flow-based numeric sizing criteria for designing structural stormwater quality control measures. The new Sacramento MS4 Permit was written to comply with the Sate Water Resources Control Board's (SWRCB) Water Quality Order 2000-11. The purpose of this technical memorandum is to:

- Review and update, if necessary, the current Sato method using more recent precipitation records and software
- Compare the Sato method design criteria to the criteria listed in the Sacramento MS4 Permit and recommend changes, if necessary
- Compare the On-Site Guidance Manual design criteria to the criteria listed in the Sacramento MS4 Permit and recommend changes, if necessary

1.2 Permit Requirements

The Sacramento MS4 Permittees received their third NPDES stormwater permit from the RQWQCB in December 2002. This permit includes very detailed and specific requirements for a Development Standards Plan (DSP). The DSP is required to describe stormwater quality control measures that each permittee will undertake to reduce pollutant discharges to the maximum extent practicable (MEP) from all new development and significant redevelopment projects.

The Sacramento MS4 Permittees are required to develop and submit a DSP that will meet the provisions outlined in the Waste Discharge Requirements Order No. R5-2002-0206 (Sacramento MS4 Permit).

The specific conditions for the numeric sizing criteria are outlined in Section C.19.c of the 2002 Sacramento MS4 Permit as follows:

> *C.19.c. Numeric Sizing Criteria: As a part of the DSP, the Permittees shall review their existing numeric sizing criteria for structural treatment BMPs* [best management practices] *and ensure that it is [sic] comparable to the following numeric sizing criteria:*
>
> ***i. Volume-based BMPs shall be designed to mitigate (infiltrate or treat) either:***
>
> *a) The volume of runoff produced from a 24-hour 85th percentile storm event as determined from the local historical rainfall record; or*
>
> *b) The volume of runoff produced from a 24-hour 85th percentile rainfall event determined as the maximized capture storm water volume for the area, from the formula recommended in Urban Runoff Quality*

Management, WEF Manual of Practice No. 23/ASCE Manual of Practice No. 87, (1998); or

c) The volume of annual runoff based on unit basin storage volume, [sic] to achieve 80 percent or more volume treatment by the method recommended in the California Storm Water Best Management Practices Handbook - Industrial/Commercial, (1993)"

ii. Flow-based BMPs shall be designed to mitigate (infiltrate or treat) either:

a) The maximum flow rate of runoff produced by the 85th percentile hourly rainfall intensity, as determined from the local historical rainfall record, multiplied by a factor of two, or

b) The maximum flow rate of runoff, as determined from local historical rainfall records, that achieves approximately the same reduction in pollutant loads and flows as achieved by mitigation of the 85th percentile hourly rainfall intensity multiplied by a factor of two.

1.3 Scope of Work

The scope of work included the following key tasks:

- Review the Sato method design criteria and assess relative advantages and disadvantages of utilizing the Sato design criteria versus more recent design criteria presented in other sources, including the 2003 *California Stormwater Best Management Practices Handbook* [2003 California BMP Handbook] (California Stormwater Quality Association, 2003), which replaces the 1993 version listed in the Sacramento MS4 permit, and the numeric sizing criteria allowed under Section C.19.c of the Sacramento MS4 Permit.

- Compare the precipitation statistics for the period 1963 through 1990 versus 1963 2002 and update the relevant precipitation statistics for comparison

- Meet with City and County staff to present and discuss findings of the comparisons prior to updating the Sato curve

- Proceed with the update using the most recent precipitation records if the decision is made to retain the Sato method

- Review the numeric BMP (stormwater quality control measure) design criteria from the On-Site Guidance Manual with respect to the alternative requirements presented under Section C.19.c of the Sacramento MS4 Permit and with respect to the results of the review of the Sato method

- Confer with the local agency staff to define technically acceptable approaches for defining numeric sizing criteria

Section 2
Review of Design Criteria for Structural Stormwater Quality Control Measures

2.1 Comparison of Precipitation Statistics for the Sato Method

The Sato method is documented in the *Optimization of Stormwater Quality Enhancement by Detention Basin for the Sacramento Metropolitan Ar*ea [Sato report] (J.F. Sato and Associates, 1991) and is based on an analysis of long-term precipitation records that approximates a continuous simulation model. Sato separated the hourly precipitation records from approximately 27 years into discrete storm events. A series of hourly precipitation records was considered to be a single storm event if it was separated by dry weather (zero precipitation) for a specified minimum interevent duration, or storm separation time. In the Sato report, three minimum interevent duration thresholds, 12, 24, and 48 hours, were used to produce three sets of long-term precipitation statistics. These three minimum interevent durations also correspond to the draw down time of the stormwater quality detention basins. However, the Sato design curve presented in the Hydrology Standards is for a storm separation time of 24 hours only.

For the storm separation analysis, Sato analyzed precipitation records from a single gage, the Sacramento Gage #047633, for the period of record from 1963 to 1990. Once the hourly precipitation records were separated into individual storm event totals, 0.1 inch was subtracted from each storm event to account for depression storage and other precipitation losses during the event. A storm event was removed from the analysis if the total precipitation of the event was less than or equal to 0.1 inch. The mean and standard deviation statistics were calculated for each minimum interevent duration (12, 24, and 48 hours) for:

- Total event precipitation (inches),
- Storm event duration (hours), and
- Actual dry period (zero precipitation) between events (hours).

Following this same methodology, CDM prepared precipitation statistics for the Sacramento Gage #047633 for three periods:

- 1936 to 2002 (all available hourly records)
- 1963 to 1990 (the period of record used in the Sato analysis)

- 1963 to 2002

The statistics were computed using a software program developed by CDM called NetSTORM. The precipitation statistics prepared by CDM are presented in Table 1 along with those prepared by Sato.

As can be seen in Table 1, the precipitation statistics prepared by CDM and Sato for the different periods of record are virtually the same. The statistics for the period from 1963 to 1990 for both authors are nearly identical for all statistics and for all storm separation durations. The mean precipitation for the 12-hour storm separation duration varied by 0.01 inch, or approximately 1 percent. This small difference is likely due to a slight difference in the period of records analyzed.

The statistics prepared by Sato for the period of 1963 to 1990 and those prepared by CDM for the periods of 1936 to 2002 and 1963 to 2002 were nearly as similar, but had some small differences in the statistics of time intervals between events. This comparison of statistics indicates that any of the three periods would yield virtually the same Sato stormwater quality basin design curve.

Table 1
Rainfall Statistics of the Sacramento Area, California (Gage #047633)

(a) 1963 - 1990 (Sato)

Storm Separation Time (hours)	Number of Storms	Precipitation (inches)		Duration (hours)		Dry Period Between Events (hours)	
		Mean	S.D.	Mean	S.D.	Mean	S.D.
12	676	0.72	0.76	13.58	16.19	208.8	425.6
24	593	0.82	0.92	20.27	25.53	251.6	459.8
48	464	1.06	1.25	39.72	52.72	328.7	513.8

(b) 1963 - 1990 (CDM)

Storm Separation Time (hours)	Number of Storms	Precipitation (inches)		Duration (hours)		Dry Period Between Events (hours)	
		Mean	S.D.	Mean	S.D.	Mean	S.D.
12	676	0.71	0.76	13.55	16.18	211.5	435.7
24	593	0.82	0.92	20.25	25.51	255.0	471.0
48	464	1.06	1.25	39.63	52.72	332.9	526.4

(c) 1963 - 2002 (CDM)

Storm Separation Time (hours)	Number of Storms	Precipitation (inches)		Duration (hours)		Dry Period Between Events (hours)	
		Mean	S.D.	Mean	S.D.	Mean	S.D.
12	997	0.72	0.75	13.99	16.31	208.9	462.0
24	869	0.84	0.91	21.16	26.73	254.2	502.9
48	671	1.09	1.32	41.41	58.06	333.6	566.5

(d) 1936 - 2002 (CDM)

Storm Separation Time (hours)	Number of Storms	Precipitation (inches)		Duration (hours)		Dry Period Between Events (hours)	
		Mean	S.D.	Mean	S.D.	Mean	S.D.
12	1686	0.72	0.77	13.77	16.16	207.6	453.7
24	1445	0.85	0.97	21.33	27.91	255.0	495.7
48	1137	1.09	1.33	40.15	57.17	328.5	553.4

2.2 Comparison of the Sato Method and Other Design Criteria Allowable Under the NPDES Permit

The Sato report presents a method to optimize the treatment capture design volume of stormwater quality detention basins in the Sacramento metropolitan area. Treatment of stormwater pollutants is based on the percentage of the total volume of stormwater that is captured by the basin and treated over a long period of time. A high percentage of the total stormwater runoff volume over time may be collected if the basin is designed to capture and treat many small, more frequent storm events. The Sato method uses a capture-curve technique to estimate the optimum detention basin design volume.

An example of a capture curve from the Sato report is shown in Figure 1. To develop this curve, the storm events described in Section 2.1 were converted to runoff volumes for each storm event using a runoff coefficient, or *C*-value, which corresponds to a particular land use or land cover. These runoff volumes were then compared to a detention basin with an assumed design volume capacity, and an overflow volume was calculated for each storm event. Under this method, the detention basin was assumed to release treated runoff at the design rate during the duration of the storm. Once the overflow was calculated for all storms in the period of record for a particular detention basin design volume capacity, the capture rate was computed for the entire period for that design volume. The curve in Figure 1 represents the results of application of this procedure for various detention basin design volume capacities for a watershed with a particular percent imperviousness, corresponding to a runoff coefficient (*C*-value) equal to 0.5.

As can be seen on Figure 1, the percent of long-term stormwater volume capture percentage increases rapidly at first with a small increase in detention design volume capacity. However, as the design volume capacity increases, the capture percentage only increases slightly. This point on the curve where the capture percentage starts to increase at a slower rate is called the "knee of the curve" and is considered to be the optimum design volume capacity. The Sato report summarized these optimized basin storage volumes for various percentages of imperviousness (*C*-values) and for storm separations of 12, 24, and 48 hours in a set of design curves, as shown in Figure 2. The Sato design curve that was incorporated into the Hydrology Standards is for the 24-hour storm separation duration only. As noted in Section 2.1, this would correspond to a 24-hour draw down period for detention basins.

Table 2 presents a summary of the features of the Sato method and provides a comparison of the Sato method with other stormwater quality control measures design methods allowed under the Sacramento MS4 Permit. Tables 3 and 4 present comparisons of the results of using the various design methods for storm separations of 24 and 48 hours. Comparisons of the Sato method and the other design criteria are described below.

Figure 1
Example Capture Curve (Open Squares) from the 1991 Sato Report

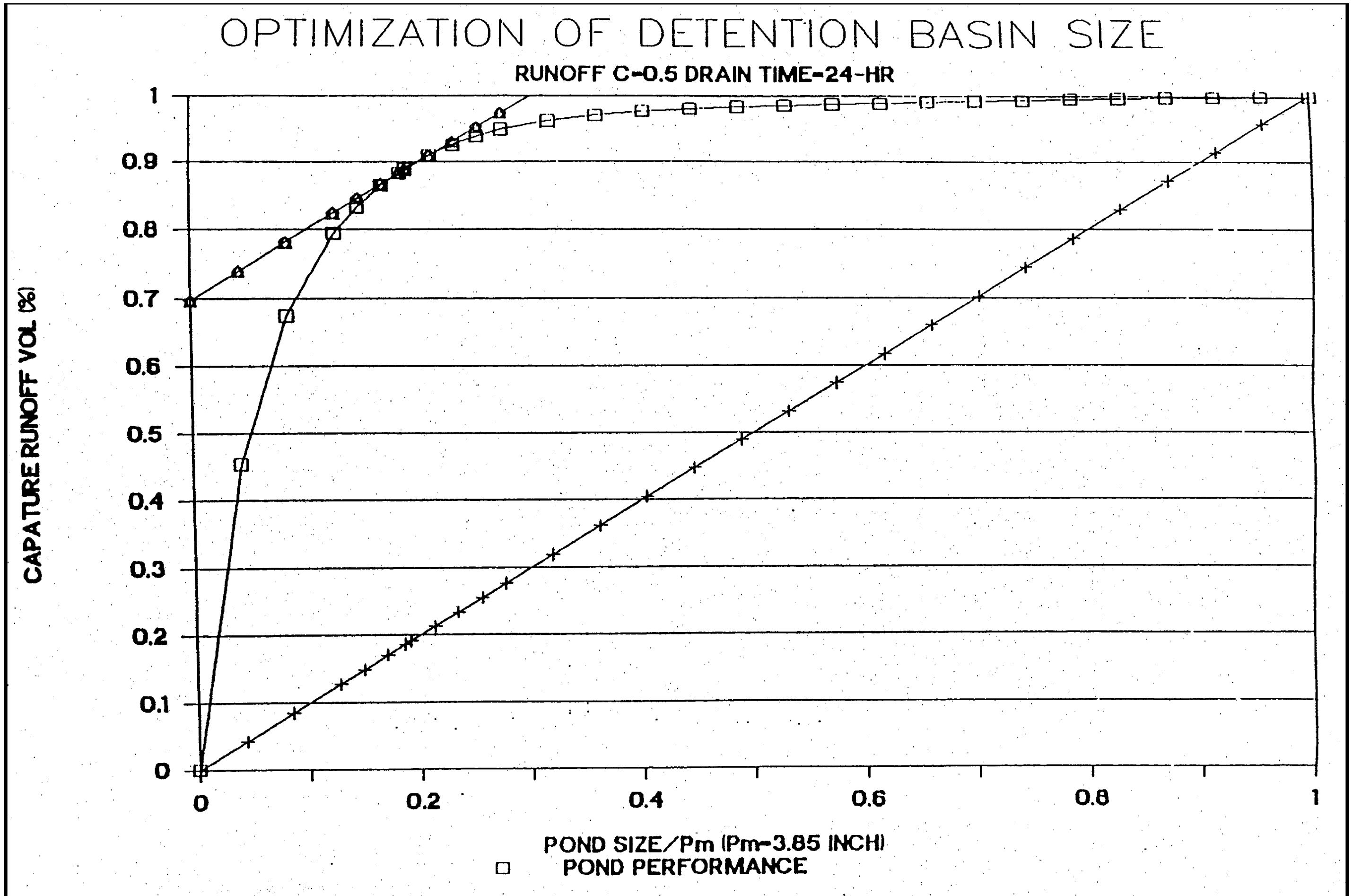


FIGURE 1 OPTIMIZATION OF DETENTION BASIN SIZE

Legend
- Normalized Volume Capture Curve
- + Normalized Pond Size Equals Runoff Volume Capture Percentage
- Tangent Line to Capture Curve with Slope of Normalized Pond Size Equaling Runoff Volume Capture Percentage

Figure 2
Sato Design Curves from the1991 Sato Report

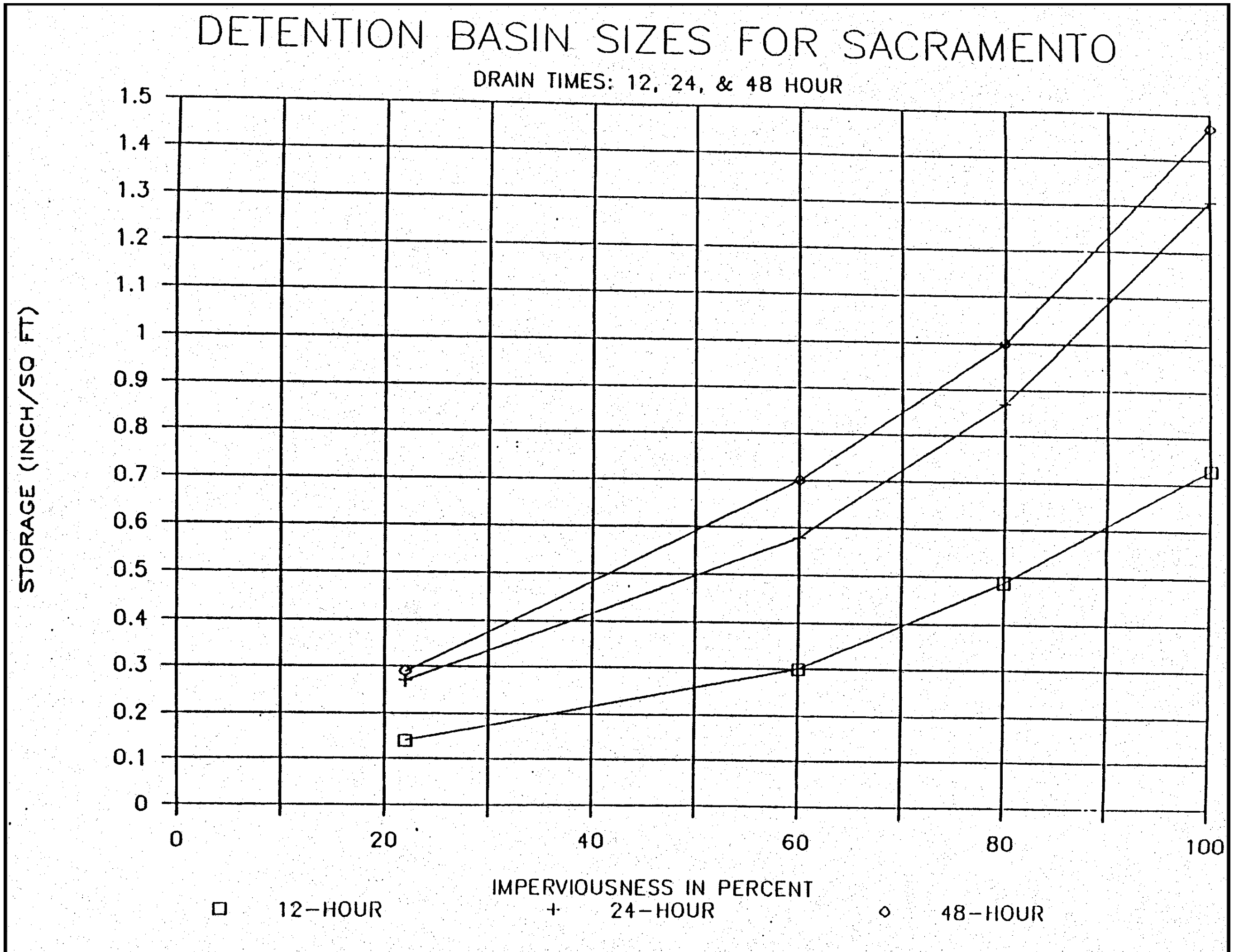


FIGURE 4 OPTIMAL SIZES OF DETENTION BASIN VERSUS IMPERVIOUSNESS IN SACRAMENTO, CALIFORNIA

Table 2
Comparison of Volume-Based Design Criteria for Stormwater Quality Detention Basins

Characteristic	Sato Method	CASQA Method	WEF/ASCE Method	85th Percentile Method	On-Site Guidance Manual Method
Design Criteria					
Approach	■ Capture curve	■ Capture curve	■ Regression equation of capture curves	■ Design storm	■ Design storm
Design Point	■ Knee of capture curve	■ Near knee of capture curve ■ Ranges from 75 to 85 percent; 80 percent capture rate assumed	■ Knee of capture curve	■ Volume of runoff from a 24-hour, 85-percentile storm event	■ First 0.5 inch of runoff
Design Volume Selection	■ One summary curve of knees of capture curves; select percent imperviousness	■ Series of capture curves ■ Select 80 percent capture rate and runoff coefficient curve ■ Curves for intermediate runoff coefficients must be interpolated	■ Set of equations and precipitation chart ■ Calculate runoff coefficient and select mean precipitation, ■ Calculate design volume	■ Permittee would need to develop methods for conversion from precipitation depths to design runoff volumes for various conditions	■ Constant 0.5 inch for all conditions ■ Multiply 0.5 inch by contributing area
Recommended Draw Down Time	■ 40 to 48 hours; 75 percent within 24 hours	■ 48 hours in most areas of Cal.; < 72 hours; 50 percent within 24 hours	■ 24 to 48 hours recommended	■ None recommended	■ Unspecified
Performance					
Volume Capture Rate	■ Varies between 87 and 89 percent	■ Constant 80 percent	■ Varies between 82 and 88 percent	■ Unspecified	■ Unspecified
Comparative Design Volume (inches) at C=0.6 and 24-Hour Draw Down	■ 0.87	■ 0.30	■ 0.54	■ Unspecified	■ 0.5
Hydrology/Basin Routing					
Statistics	■ Storm event separation technique	■ Storm event separation technique	■ Storm event separation technique	■ Unspecified	■ Unspecified
Travel Time of Runoff					■ Neglected
Area Reduction Factor					■ Not applicable

Table 2 (Continued)
Comparison of Volume-Based Design Criteria for Stormwater Quality Detention Basins

Characteristic	Sato Method	CASQA Method	WEF/ASCE Method	85th Percentile Method	On-Site Guidance Manual Method
Hydrology/Basin Routing (continued)					
Gage Used	■ Sacramento Gage (047633)	■ Sacramento Gage (047633)	■ Unspecified	■ Unspecified	■ Unspecified
Period of Record Used	■ 1963-1990	■ 1936-2002	■ Unspecified	■ Unspecified	■ Unspecified
Minimum Interevent Time Duration	■ 24 hours for Sato curve (12 and 48hours available in Sato Report)	■ 24 and 48 hours	■ 6 hours	■ Unspecified	■ Not applicable
Effective Precipitation	■ Initial abstraction 0.1 inch per storm event; constant rate loss neglected	■ Depression storage losses of 0.06 inch/hour; evaporation of 0.15 inch/day; constant rate loss neglected	■ 0.1 inch precipitation for a storm to produce incipient runoff	■ Unspecified	■ Unspecified
Runoff Volume Calculation	■ Runoff coefficient multiplied by effective precipitation	■ Runoff coefficient multiplied by effective precipitation (STORM program)	■ Runoff coefficient multiplied by effective precipitation (STORM program)	■ Unspecified	■ Unspecified
Reference for Runoff Coefficient	■ 1983 EPA Nationwide Urban Runoff Program (NURP)	■ CA BMP Handbook (no reference listed)	■ 1983 EPA Nationwide Urban Runoff Program (NURP)	■ Unspecified	■ Not applicable
Depth of Water in Pond at Beginning of Storm	■ Empty	■ Empty	■ Empty	■ Unspecified	■ Unspecified
Release Rate During Storm Event	■ Average rate of basin volume divided by draw down time	■ Average rate of basin volume divided by draw down time	■ Unspecified	■ Unspecified	■ Unspecified
Applicability of Criteria					
Watershed Area	■ <640 acres	■ >5 acres, <100 acres	■ <640 acres	■ Unspecified	■ <50 acres

Table 3
Comparison of Design Volumes Calculated for Stormwater Quality Detention Basins Using Various Criteria—24-Hour Separation Interval

Variable	Sato Method	CASQA Method	WEF/ASCE Method	85th Percentile Method
Runoff Coefficient	0.2	0.2	0.2	Not Available
Volume Capture Rate Percentage	87	80	Not Available	Not Available
Design Unit Pond Volume (in. per unit area)	0.27	0.11	0.18	Not Available
Percent Difference in Design Volume Compared to Sato Method	Not Applicable	-59	-33	Not Applicable
Runoff Coefficient	0.4	0.4	0.4	Not Available
Volume Capture Rate Percentage	89	80	Not Available	Not Available
Design Unit Pond Volume (in. per unit area)	0.58	0.2	0.36	Not Available
Percent Difference in Design Volume Compared to Sato Method	Not Applicable	-66	-38	Not Applicable
Runoff Coefficient	0.6	0.6	0.6	Not Available
Volume Capture Rate Percentage	88	80	Not Available	Not Available
Design Unit Pond Volume (in. per unit area)	0.87	0.30	0.54	Not Available
Percent Difference in Design Volume Compared to Sato Method	Not Applicable	-66	-38	Not Applicable
Runoff Coefficient	0.9	0.9	0.9	Not Available
Volume Capture Rate Percentage	89	80	Not Available	Not Available
Design Unit Pond Volume (in. per unit area)	1.31	0.46	0.81	Not Available
Percent Difference in Design Volume Compared to Sato Method	Not Applicable	-65	-37	Not Applicable

Table 4
Comparison of Design Volumes Calculated for Stormwater Quality Detention Basins Using Various Criteria—48-Hour Separation Interval

Variable	Sato Method	CASQA Method	WEF/ASCE Method	85th Percentile Method
Runoff Coefficient	0.2	0.2	0.2	Not Available
Volume Capture Rate Percentage	76	80	Not Available	Not Available
Design Unit Pond Volume (in. per unit area)	0.29	0.17	0.22	Not Available
Percent Difference in Design Volume Compared to Sato Method	Not Applicable	-41	-24	Not Applicable
Runoff Coefficient	0.4	0.4	0.4	Not Available
Volume Capture Rate Percentage	81	80	Not Available	Not Available
Design Unit Pond Volume (in. per unit area)	0.70	0.3	0.45	Not Available
Percent Difference in Design Volume Compared to Sato Method	Not Applicable	-57	-38	Not Applicable
Runoff Coefficient	0.6	0.6	0.6	Not Available
Volume Capture Rate Percentage	81	80	Not Available	Not Available
Design Unit Pond Volume (in. per unit area)	1.00	0.42	0.67	Not Available
Percent Difference in Design Volume Compared to Sato Method	Not Applicable	-58	-33	Not Applicable
Runoff Coefficient	0.9	0.9	0.9	Not Available
Volume Capture Rate Percentage	80	80	Not Available	Not Available
Design Unit Pond Volume (in. per unit area)	1.47	0.66	1.01	Not Available
Percent Difference in Design Volume Compared to Sato Method	Not Applicable	-55	-31	Not Applicable

2.2.1 Volume-Based Versus Flow-Based Design Criteria

The Sato method is used to optimize the total volume of stormwater that is captured over a long period of time by a stormwater quality control detention basin. That is, it is a volume-based method of design. This approach is appropriate for measures such as inline structural detention basins.

However, for other types of measures, a flow-based design is appropriate; that is, the measure is designed to handle a certain peak flow. For example, a vegetative swale is one that uses a flow-based design. Still other measures must have a volume-based and a flow-based design. A common example of such a case is an off-line detention basin (extended dry basin). For an off-line detention basin, the volume of the basin is designed using volume-based criteria, and the diversion structure that diverts water from the main channel to the basin is designed using flow-based criteria. The Sato method only provides criteria for the volume-based design and does not provide any criteria for the flow-based design.

Therefore, the comparisons below between the Sato method and the other design criteria are only for the volume-based design criteria. Flow-based design criteria is discussed in Section 2.3 for the comparison of the design criteria of the On-Site Guidance Manual and the criteria listed in the Sacramento MS4 Permit.

2.2.2 Comparison of the Sato Method and the CASQA Method

The design criteria in the 2003 California BMP Handbook and the Sato Method are similar methods. The two criteria are compared in Table 2. Like the Sato Method, the method published by the California Stormwater Quality Association (CASQA method) in the California BMP Handbook is a knee-of-the-capture curve approach. Figures 3 and 4 show the design capture curves from the 2003 California BMP Handbook for the Sacramento 5 ESE gage (or #047633) for the 24- and 48-hour storm separation durations, respectively. These capture curves are for various runoff coefficients (*C*-values) and have similar shapes as those for the Sato method.

One of the main differences with the CASQA method is that the designer must interpolate between curves for *C*-values not shown, leaving more opportunity for interpretation. Another significant difference is that the California BMP Handbook recommends design of detention basins for an 80 percent capture rate for all conditions, which, in general, is close but not necessarily at the knee of the curve. As shown in Tables 3 and 4, this approach results in volume capture rates that are usually lower than those resulting from the Sato method.

Based on the comparisons presented in Table 3 and 4, the CASQA method generally yields unit basin design volume capacities (depth per unit of watershed area) that are more than 50 percent lower than the Sato Method at the same *C*-value. These results are unexpected because the methods employ very similar approaches. However, the

Sato method, although yielding larger design volume capacities, does comply with the CASQA method.

Figure 3
Capture Curves for the Sacramento Gage from the 2003 California BMP Handbook--24-Hour Drawdown

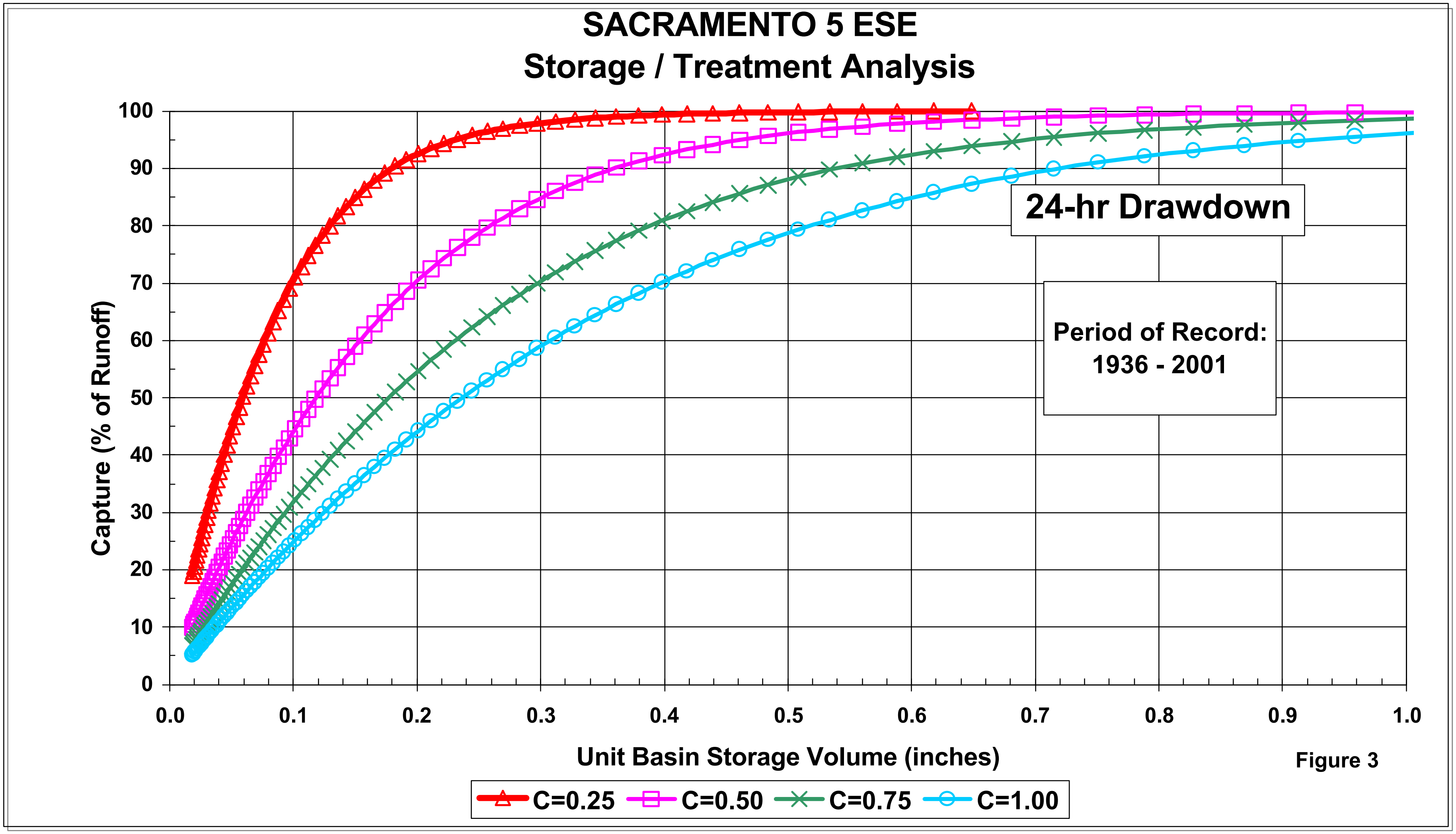
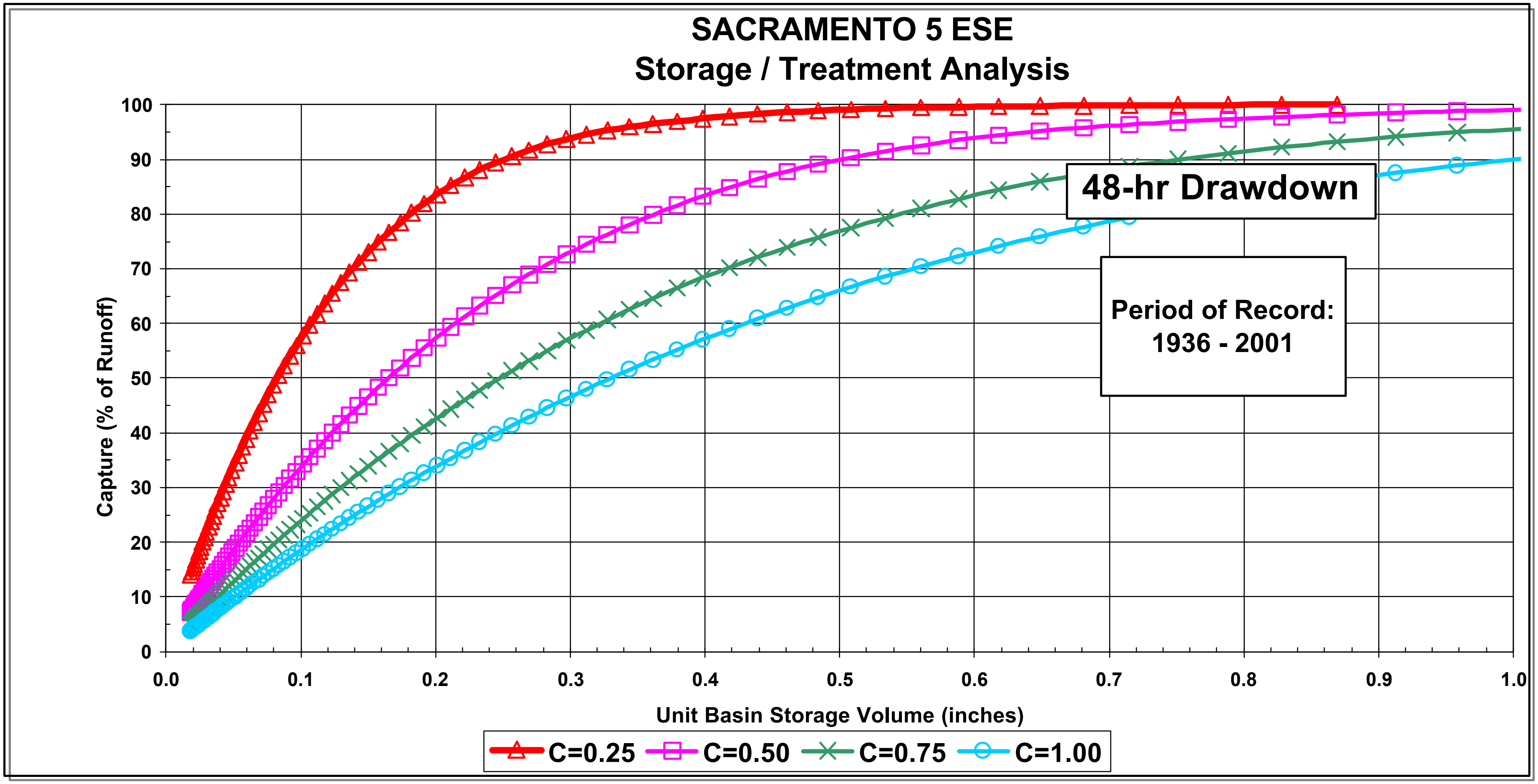


Figure 4
Capture Curves for the Sacramento Gage from the 2003 California BMP Handbook--48-Hour Drawdown



2.2.3 Comparison of the Sato Method and the WEF/ASCE Method

The design criteria in the Water Environment Federation/American Society of Civil Engineers (WEF/ASCE) manual of practice *Urban Runoff Quality Management* (Water Environment Federation and American Society of Civil Engineers, 1998) are similar to those of the Sato method. The two criteria are compared in Table 2. The WEF/ASCE method is based on a knee-of-the-capture curve approach. However, using this method, stormwater detention basin design volumes are not selected from the original capture curves. Instead, a set of regression equations was developed for the optimal capture rates from capture curves developed for different meteorological regions of the United States. The equations are based on a *C*-value, a regression coefficient that depends on the draw down time of the basin, and the mean storm precipitation depth, all of which are provided in the manual. This method is easy to use but may not be as accurate of a method, such as the Sato method, that is developed with precipitation data specifically from the study area. As shown in Tables 3 and 4, the long-term runoff volume capture rate for this method cannot be obtained from the equations but should be in the same range as for the Sato method.

Tables 3 and 4 present a comparison of the results of using the Sato method and the WEF/ASCE method for storm separations of 24 and 48 hours, respectively. For the same *C*-value, in general, use of the WEF/ASCE method generally yields unit basin design volume capacities (depth per unit of watershed area) that are approximately one third lower than those computed using the Sato method. These results are unexpected because the methods are so similar. The cause of this difference has not been identified. However, the Sato method, although yielding larger design volume capacities, does comply with the WEF/ASCE method.

2.2.4 Comparison of the Sato Method and the Volume-Based 85th Percentile Method

Using the design criteria listed in Section C.19.c.i.a of the Sacramento MS4 Permit (85th Percentile method), a detention basin would be designed to capture and treat the volume of runoff produced from a 24-hour, 85th percentile storm event as determined from the local historical precipitation record. This method is different than the Sato method. The two criteria are compared in Table 2.

Whereas the Sato method is based on overall volume captured over a long period of time, the 85th Percentile method is based on capturing a single storm event. However, design for this size storm event has been reported to yield an 80 percent volume capture rate for other areas. This design precipitation would need to be developed for the Sacramento area. Therefore, the capture rate and design volume that would result from using the 85th Percentile method is unknown. Also, the 85th Percentile method does not specify a hydrologic method to convert from precipitation depth to runoff volume; one would need to be developed by the Sacramento MS4 Permittees. More analysis would need to be done to determine if the Sato method complies with the 85th Percentile method.

2.3 Comparison of the Design Criteria Guidance Manual and Other Design Criteria Allowable Under the NPDES Permit

The City and County of Sacramento provide design guidance for on-site stormwater quality control measures in the *Guidance Manual for On-Site Stormwater Quality Control Measures* [On-Site Guidance Manual] (Sacramento County Public Works Agency and City of Sacramento Department of Utilities and Public Work, 2000). The On-Site Guidance Manual defines on-site stormwater quality control measures as being for drainage areas of 100 acres or less. The On-Site Guidance Manual provides general design criteria for both volume-based and flow-based design. Volume-based stormwater control measures are designed using the water quality volume (WQV), which the manual defines as the first one-half inch of runoff. Flow-based stormwater control measures are designed using the water quality flow (WQF), which the manual defines as the peak flow rate of runoff associated with the 2-year, 6-hour storm event. Approved stormwater quality control measures designed with volume-based criteria are sand filters, infiltration trenches and basins, and porous paving blocks. The approved stormwater control measure designed with flow-based criteria is the vegetative swale. The On-Site Guidance Manual does not explicitly list detention basins as acceptable stormwater quality control measures.

The On-Site Guidance Manual method applies a different approach than the Sato method. Whereas the objective of the Sato method is to capture a large percentage of stormwater runoff over a long period of time, the primary control strategy for the On-Site Guidance Manual methods is to treat the first flush flow or volume of the stormwater runoff. This approach is based on the theory that much of the stormwater pollutants are transported from the watershed in the first part of a storm event. Stormwater in excess of the first flush flow or volume is diverted around or through the stormwater quality control measure without treatment.

Table 2 is a summary of the features of the volume-based criteria of the On-Site Guidance Manual method. Also in Table 2 is a comparison of the volume-based criteria of the On-Site Guidance Manual method with other design methods allowed under the Sacramento MS4 Permit. Tables 5 and 6 present a comparison of the results of using the various volume-based design methods for storm separations of 24 and 48 hours, respectively. Comparisons of the On-Site Guidance Manual method and the other volume-based design criteria are described below. The flow-based design criteria are described separately below in Section 2.3.

Table 5
Comparison of Design Volumes Calculated for Stormwater Quality Control Measures Using Various Criteria—24-Hour Separation Interval

Variable	On-Site Guidance Manual Method	Sato Method	CASQA Method	WEF/ASCE Method	85th Percentile Method
Runoff Coefficient	Not Applicable	0.2	0.2	0.2	Not Available
Volume Capture Percentage	Not Available	87	80	Not Available	Not Available
Design Unit Pond Volume (in.)	0.5	0.27	0.11	0.18	Not Available
Percent Difference in Design Volume Compared to On-Site Guidance Manual Method	Not Applicable	-46	-78	-64	Not Applicable
Runoff Coefficient	Not Applicable	0.4	0.4	0.4	Not Available
Volume Capture Percentage	Not Available	89	80	Not Available	Not Available
Design Unit Pond Volume (in.)	0.5	0.58	0.2	0.36	Not Available
Percent Difference in Design Volume Compared to On-Site Guidance Manual Method	Not Applicable	16	-60	-28	Not Applicable
Runoff Coefficient	Not Applicable	0.6	0.6	0.6	Not Available
Volume Capture Percentage	Not Available	88	80	Not Available	Not Available
Design Unit Pond Volume (in.)	0.5	0.87	0.30	0.54	Not Available
Percent Difference in Design Volume Compared to On-Site Guidance Manual Method	Not Applicable	74	-40	8	Not Applicable
Runoff Coefficient	Not Applicable	0.9	0.9	0.9	Not Available
Volume Capture Percentage	Not Available	89	80	Not Available	Not Available
Design Unit Pond Volume (in.)	0.5	1.31	0.46	0.81	Not Available
Percent Difference in Design Volume Compared to On-Site Guidance Manual Method	Not Applicable	62	-8	62	Not Applicable

Table 6
Comparison of Design Volumes Calculated for Stormwater Quality Control Measures Using Various Criteria—48-Hour Separation Interval

Variable	Guidance Manual for On-Site Stormwater Quality Control Measures	Sato Method	CASQA Method	WEF Method	85th Percentile Method
Runoff Coefficient	Not Applicable	0.2	0.2	0.2	Not Available
Volume Capture Percentage	Not Available	76	80	Not Available	Not Available
Design Unit Pond Volume (in.)	0.5	0.29	0.17	0.22	Not Available
Percent Difference in Design Volume Compared to On-Site Guidance Manual Method	Not Applicable	-42	-66	-56	Not Applicable
Runoff Coefficient	Not Applicable	0.4	0.4	0.4	Not Available
Volume Capture Percentage	Not Available	81	80	Not Available	Not Available
Design Unit Pond Volume (in.)	0.5	0.70	0.3	0.45	Not Available
Percent Difference in Design Volume Compared to On-Site Guidance Manual Method	Not Applicable	40	-40	-10	Not Applicable
Runoff Coefficient	Not Applicable	0.6	0.6	0.6	Not Available
Volume Capture Percentage	Not Available	81	80	Not Available	Not Available
Design Unit Pond Volume (in.)	0.5	1.00	0.42	0.67	Not Available
Percent Difference in Design Volume Compared to On-Site Guidance Manual Method	Not Applicable	100	-16	34	Not Applicable
Runoff Coefficient	Not Applicable	0.9	0.9	0.9	Not Available
Volume Capture Percentage	Not Available	80	80	Not Available	Not Available
Design Unit Pond Volume (in.)	0.5	1.47	0.66	1.01	Not Available
Percent Difference in Design Volume Compared to On-Site Guidance Manual Method	Not Applicable	194	32	102	Not Applicable

2.3.1 Comparison of the Volume-Based On-Site Guidance Manual Method and the 2003 CASQA Method

The design criteria in the 2003 California BMP Handbook are different than the criteria of the On-Site Guidance Manual. The two criteria are compared in Table 5. The CASQA method from the 2003 California BMP Handbook is a capture curve approach, as shown in Figures 3 and 4. The design volume for the CASQA method is the volume at which an 80 percent capture rate is achieved. This design volume varies by *C*-value. The On-Site Guidance Manual method specifies a constant 0.5-inch design volume per unit area for all conditions.

Tables 5 and 6 present a comparison of the results of using the On-Site Guidance Manual method and the CASQA method for storm separations of 24 and 48 hours, respectively. The CASQA method yields unit design volume capacities (depth per unit of watershed area) that are in almost all cases substantially lower than those unit design volumes computed using the On-Site Guidance Manual method. For only one case, a *C*-value of 0.9 and a storm separation interval of 48 hours, did the CASQA method yield higher results—0.66 inch versus 0.5 inch for the On-Site Guidance Manual. A *C*-value of 0.9 would be representative of an almost completely impervious watershed. Therefore, as compared to the CASQA method, in general, the On-Site Guidance Manual method would yield basins designed with larger storage volumes. Because these basins would likely be designed to release small storm events more quickly, the larger storage volumes would not necessarily provide higher levels of water quality treatment. The On-Site Guidance Manual method does not comply with the requirements of the CASQA method for some land-use conditions.

2.3.2 Comparison of the Volume-Based On-Site Guidance Manual Method and the WEF/ASCE Method

The design criteria in the WEF/ASCE method are different than the criteria of the On-Site Guidance Manual. The two criteria are compared in Table 2. The WEF/ASCE method is based on a capture curve approach. The design volume for this method varies by *C*-value. The On-Site Guidance Manual method specifies a constant 0.5-inch design volume per unit area for all conditions.

Tables 5 and 6 present a comparison of the results of using the On-Site Guidance Manual method and the WEF/ASCE method for storm separations of 24 and 48 hours, respectively. The WEF/ASCE method yields unit design volume capacities (depth per unit of watershed area) that are lower for *C*-values less than approximately 0.6 and higher unit design volumes for *C*-values greater than 0.6. The On-Site Guidance Manual method does not comply with the requirements of the WEF/ASCE method for some land-use conditions.

2.3.3 Comparison of the Volume-Based On-Site Guidance Manual Method and the 85th Percentile Method

Using the design criteria listed in Section C.19.c.i.a of the Sacramento MS4 Permit (85th Percentile method), a detention basin would be designed to capture entirely the volume of runoff produced from a 24-hour, 85th percentile storm event as determined from the local historical precipitation record. This method is different than the On-Site Guidance Manual method. The two criteria are compared in Table 2.

The methods are similar in that they are based on capturing a single sized storm event. However, the On-Site Guidance Manual method requires that measures be designed for 0.5 inch of runoff, whereas the 85th Percentile method requires that measures be designed for a certain sized precipitation depth. The translation from precipitation to runoff is not specified for the 85th Percentile method. Also, this design precipitation would need to be developed for the Sacramento area. Therefore, the capture rate and design volume that would result from using the 85th Percentile method is unknown, as is that for the On-Site Guidance Manual method. Furthermore, to use the 85th Percentile method, the Sacramento MS4 Permittees would need to select a hydrologic method to convert from precipitation depth to runoff volume. More work would need to be done to determine whether the On-Site Guidance Manual method complies with the 85th Percentile method.

2.3.4 Comparison of the Flow-Based On-Site Guidance Manual Method and Other Acceptable Methods

A flow-based design is used for stormwater quality control measures such as vegetative swales and diversion structures of off-line structural stormwater quality control measures. The On-Site Guidance Manual provides flow-based criteria that require design for runoff produced by a 2-year, 6-hour storm event. The intensity of such a storm event is listed as 0.18 inch/hour in Table 4-2 of the Hydrology Standards. The On-Site Guidance Manual provides the rational method to convert this precipitation intensity to a runoff peak flow rate.

Section 19.C.ii.a of the Sacramento MS4 Permit requires that flow-based measures be designed for the maximum (peak) flow rate of runoff produced by the 85th percentile hourly precipitation intensity multiplied by a factor of two, referred to here as the flow-based 85th Percentile method. This criterion is the same as the one prescribed by the 2003 California BMP Handbook, the flow-based CASQA method. From Appendix *D* of the 2003 California BMP Handbook, the 85th percentile hourly precipitation intensity is approximately 0.09 inch/hour for the Sacramento gage. Multiplying by two, the required intensity is 0.18 inch/hour. This intensity is by coincidence the same as required for the On-Site Guidance Manual. The flow-based On-Site Guidance Manual method complies with both the flow-based 85th Percentile method and with the flow-based CASQA method. However, if the hydrology of the Sacramento gage changes, which is not likely, the flow-based On-Site Guidance Manual method could fall out of compliance.

The Sacramento MS4 Permit also does not list any preferred method for converting the design precipitation intensity to a runoff flow rate. Both the On-Site Guidance Manual and the 2003 California BMP Handbook for the CASQA method provides the rational method to convert the design precipitation intensity to a runoff peak flow rate.

Section 3
Conclusions and Recommendations

This section presents conclusions and recommendations based on the analysis presented in Section 2.

3.1 Comparison of Precipitation Statistics for the Sato Method

The precipitation statistics originally prepared by Sato for the period of 1963 to 1990 and those prepared by CDM for the periods of 1936 to 2002 and 1963 to 2002 are nearly identical. This comparison of statistics suggests that use of any of these three precipitation records would result in similar stormwater quality basin storage design curves and there is no reason to update the Sato method solely to account for differences in the precipitation record.

In the future, the Sacramento MS4 Permittees might consider performing a similar analysis for precipitation gages in the eastern portion of the County to determine if the use of these gages would result in significantly different design curves.

3.2 Comparison of the Current Design Criteria with Other Design Criteria Allowable Under the NPDES Permit

3.2.1 Volume-Based Criteria Comparisons

Comparison of the Sato Method and the CASQA Method. For the same *C*-value, application of the CASQA method results in unit basin design volume capacities (depth per unit of watershed area) that are more than 50 percent lower than unit basin design volume capacities computed using the Sato method. However, the Sato method, although yielding larger design volume capacities, does comply with the CASQA method.

Comparison of the Sato Method and the WEF/ASCE Method. For the same *C*-value, application of the WEF/ASCE method results in unit basin design volume capacities (depth per unit of watershed area) that are approximately one third lower than unit basin design volume capacities computed using the Sato method. However, the Sato method, although yielding larger design volume capacities, does comply with the WEF/ASCE method.

Comparison of the Sato Method and the 85th Percentile Method

The capture rate and design volume that would result from using the 85th Percentile method is unknown, as is that for the On-Site Guidance Manual method. In order to use the 85th Percentile method, the Sacramento MS4 Permittees would need to develop a hydrologic method to convert from precipitation depth to runoff volume. More work would need to be done to determine whether the Sato method complies with the 85th Percentile method.

Comparison of the Volume-Based On-Site Guidance Manual Method and the CASQA Method

For typical *C*-values, use of the CASQA method results in unit basin design volume capacities (depth per unit of watershed area) that is in almost all cases lower (i.e., up to 78 percent lower) than unit basin design volume capacities computed using the On-Site Guidance Manual method. For only one case, a *C*-value of 0.9 and a draw down period of 48 hours, did the CASQA method yield higher results—0.66 inch versus 0.5 inch for the On-Site Guidance Manual. The On-Site Guidance Manual method does not comply with the requirements of the CASQA method for some land-use conditions.

Comparison of the Volume-Based On-Site Guidance Manual Method and the WEF/ASCE Method

For *C*-values less than 0.6, use of the WEF/ASCE method yields unit design volumes (depth per unit of watershed area) that are lower than unit design volumes computed using the On-Site Guidance Manual method. For *C*-values greater than 0.6, the WEF/ASCE method yields higher results. The On-Site Guidance Manual method does not comply with the requirements of the WEF/ASCE method for some land-use conditions.

Comparison of the Volume-Based On-Site Guidance Manual Method and the 85th Percentile Method

The capture rate and design volume that would result from using the 85th Percentile method is unknown, as is that for the On-Site Guidance Manual method. In order to use the 85th Percentile method, the Sacramento MS4 Permittees would need to develop a hydrologic method to convert from precipitation depth to runoff volume. More work would need to be done to determine whether the On-Site Guidance Manual method complies with the 85th Percentile method.

3.2.2Flow-Based Criteria Comparisons

Comparison of the Flow-Based On-Site Guidance Manual Method and other Acceptable Methods

Section 19.C.ii.a of the Sacramento MS4 Permit requires that flow-based measures be designed for the maximum (peak) flow rate of runoff produced by the 85th percentile hourly precipitation intensity multiplied by a factor of two, referred to here as the flow-based 85th Percentile method. This criterion is the same as the one prescribed by the 2003 California BMP Handbook, the flow-based CASQA method. The 85th percentile hourly precipitation intensity multiplied by two is 0.18 inch/hour. This intensity is by coincidence the same as required for the On-Site Guidance Manual. The flow-based On-Site Guidance Manual method complies with both the flow-based 85th Percentile method and with the flow-based CASQA method. However, if the hydrology of the Sacramento gage changes, which is not likely, the flow-based On-Site Guidance Manual method could fall out of compliance.

3.3 Recommendations for Updating Numeric Sizing Criteria

- To comply with the requirements under the Sacramento MS4 Permit, it is recommended that the 2003 California BMP Handbook and the CASQA methods, both volume-based and flow-based, be used as the basis for one centralized stormwater quality control measure guidance manual for both on-site- and regional-sized measures. This approach would also establish a consistent basis for plan review and compliance, provide a measure of equality in stormwater quality control measure implementation, facilitate evaluation and improvement of stormwater quality control technologies, and reduce confusion as to which manual is applicable to which design situation.

- As shown in Table 2, both the CASQA and the Sato methods are applicable to relatively small drainage areas, that is to say, on-site drainage areas. This limitation exists because both methods are based on simplified hydrologic models. They both yield more accurate results for smaller watersheds and less accurate results, in general, for larger watersheds. For larger watersheds and regional stormwater quality control measures, they are excellent planning tools. However, a more detailed hydrologic analysis with more sophisticated flow routing, such as can be done with the SWMM modeling software, should be required for the final design for regional structural stormwater quality control measures.

Section 4 References

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